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Chapter 7 - Body Weight Studies

7. BODY WEIGHT STUDIES

There are several physiological factors needed to calculate potential exposures. These include skin surface area (see Volume I, Section 6), inhalation rate (see Volume I, Section 5) life expectancy (see Volume I, Section 8), and body weight. The average daily dose is typically normalized to the average body weight of the exposed population. If exposure occurs only during childhood years, the average child body weight during the exposure period should be used to estimate risk (U.S. EPA, 1989). Conversely, if adult exposures are being evaluated, an adult body weight value should be used.

The purpose of this section is to describe published studies on body weight for the general U.S. population. The studies have been classified as either key or relevant studies, based on the criteria described in Volume I, Section 1.3.1. Recommended values are based on the results of key studies, but relevant studies are also presented to provide the reader with added perspective on the current state of knowledge pertaining to body weight.

7.1. KEY BODY WEIGHT STUDY

Hamill et al. (1979) - Physical Growth: National Center for Health Statistics Percentiles - A National

Center for Health Statistics (NCHS) Task Force that included academic investigators and representatives from CDC Nutrition Surveillance Program selected, collated, integrated, and defined appropriate data sets to generate growth curves for the age interval: birth to 36 months developed (Hamill et al., 1979). The percentile curves were for assessing the physical growth of children in the U.S. They are based on accurate measurements made on large nationally representative samples of children (Hamill et al., 1979). Smoothed percentile curves were derived for body weight by age (Hamill et al., 1979). Curves were developed for boys and for girls. The data used to construct the curves were provided by the Fels Research Institute, Yellow Springs, Ohio. These data were from an ongoing longitudinal study where anthropometric data from direct measurements are collected regularly from participants (~1,000) in various areas of the U.S. The NCHS used advanced statistical and computer technology to generate the growth curves. Table 7-1 presents the percentiles of weight by sex and age. Figures 7-1 and 7-2 present weight by age percentiles for boys and for girls aged birth to 36 months, respectively. Limitations of this study are that mean body weight values were not reported and the data are more

| Table 7-1. Smoothed Percentiles of Weight (in kg) by Sex and Age: Statistics from NCHS and Data from Fels Research Institute, Birth to 36 Months | | | | | | | |
|---|----------------------------------|-------|-------|-------|-------|-------|-------|
| Sex and Age | Smoothed ^a Percentile | | | | | | |
| | 5th | 10th | 25th | 50th | 75th | 90th | 95th |
| Weight in Kilograms | | | | | | | |
| Male | | | | | | | |
| Birth | 2.54 | 2.78 | 3.00 | 3.27 | 3.64 | 3.82 | 4.15 |
| 1 Month | 3.16 | 3.43 | 3.82 | 4.29 | 4.75 | 5.14 | 5.38 |
| 3 Months | 4.43 | 4.78 | 5.32 | 5.98 | 6.56 | 7.14 | 7.37 |
| 6 Months | 6.20 | 6.61 | 7.20 | 7.85 | 8.49 | 9.10 | 9.46 |
| 9 Months | 7.52 | 7.95 | 8.56 | 9.18 | 9.88 | 10.49 | 10.93 |
| 12 Months | 8.43 | 8.84 | 9.49 | 10.15 | 10.91 | 11.54 | 11.99 |
| 18 Months | 9.59 | 9.92 | 10.67 | 11.47 | 12.31 | 13.05 | 13.44 |
| 24 Months | 10.54 | 10.85 | 11.65 | 12.59 | 13.44 | 14.29 | 14.70 |
| 30 Months | 11.44 | 11.80 | 12.63 | 13.67 | 14.51 | 15.47 | 15.97 |
| 36 Months | 12.26 | 12.69 | 13.58 | 14.69 | 15.59 | 16.66 | 17.28 |
| Female | | | | | | | |
| Birth | 2.36 | 2.58 | 2.93 | 3.23 | 3.52 | 3.64 | 3.81 |
| 1 Month | 2.97 | 3.22 | 3.59 | 3.98 | 4.36 | 4.65 | 4.92 |
| 3 Months | 4.18 | 4.47 | 4.88 | 5.40 | 5.90 | 6.39 | 6.74 |
| 6 Months | 5.79 | 6.12 | 6.60 | 7.21 | 7.83 | 8.38 | 8.73 |
| 9 Months | 7.00 | 7.34 | 7.89 | 8.56 | 9.24 | 9.83 | 10.17 |
| 12 Months | 7.84 | 8.19 | 8.81 | 9.53 | 10.23 | 10.87 | 11.24 |
| 18 Months | 8.92 | 9.30 | 10.04 | 10.82 | 11.55 | 12.30 | 12.76 |
| 24 Months | 9.87 | 10.26 | 11.10 | 11.90 | 12.74 | 13.57 | 14.08 |
| 30 Months | 10.78 | 11.21 | 12.11 | 12.93 | 13.93 | 14.81 | 15.35 |
| 36 Months | 11.60 | 12.07 | 12.99 | 13.93 | 15.03 | 15.97 | 16.54 |
| ^a Smoothed by cubic-spline approximation. Source: Hamill et al., 1979. | | | | | | | |

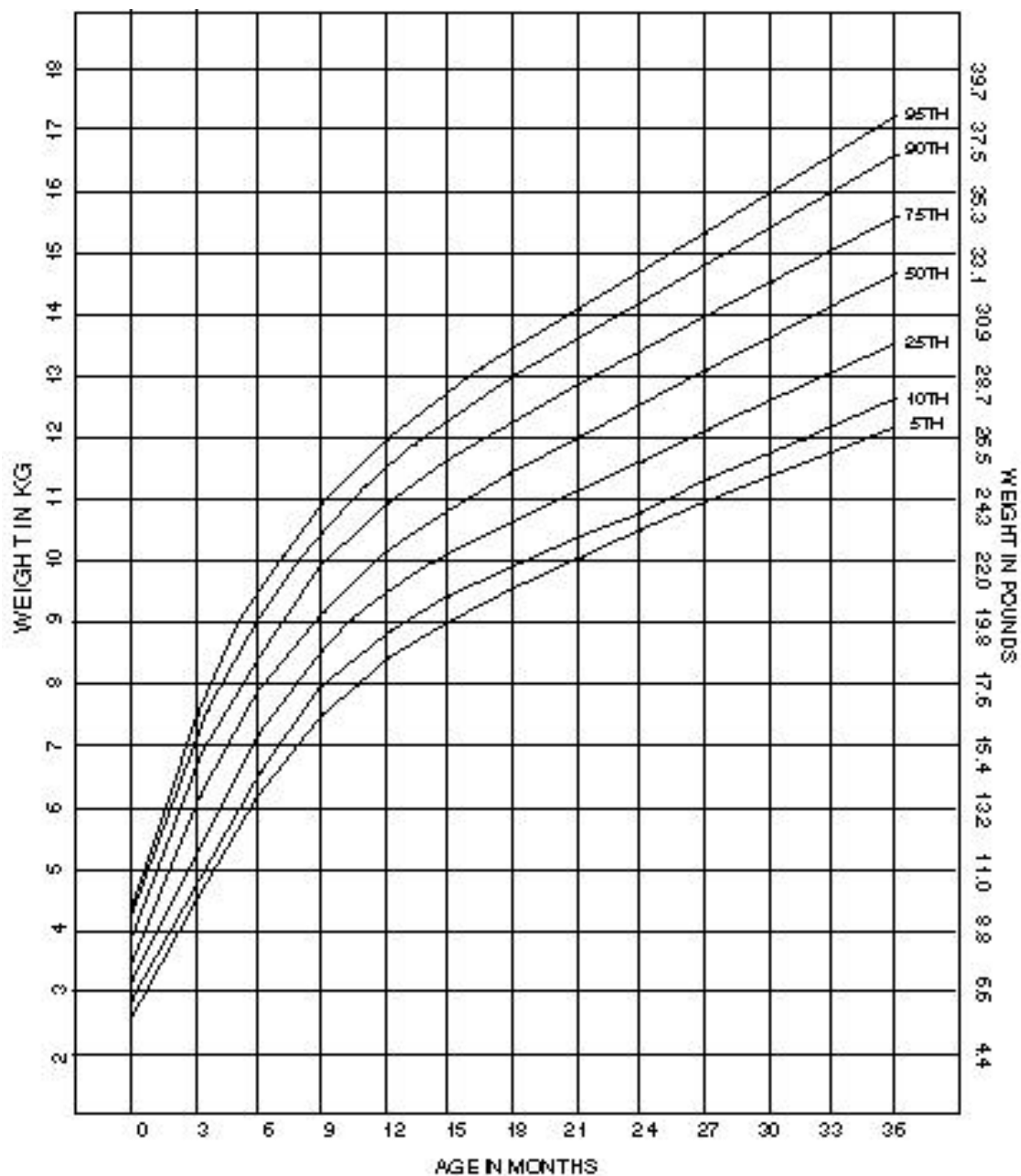
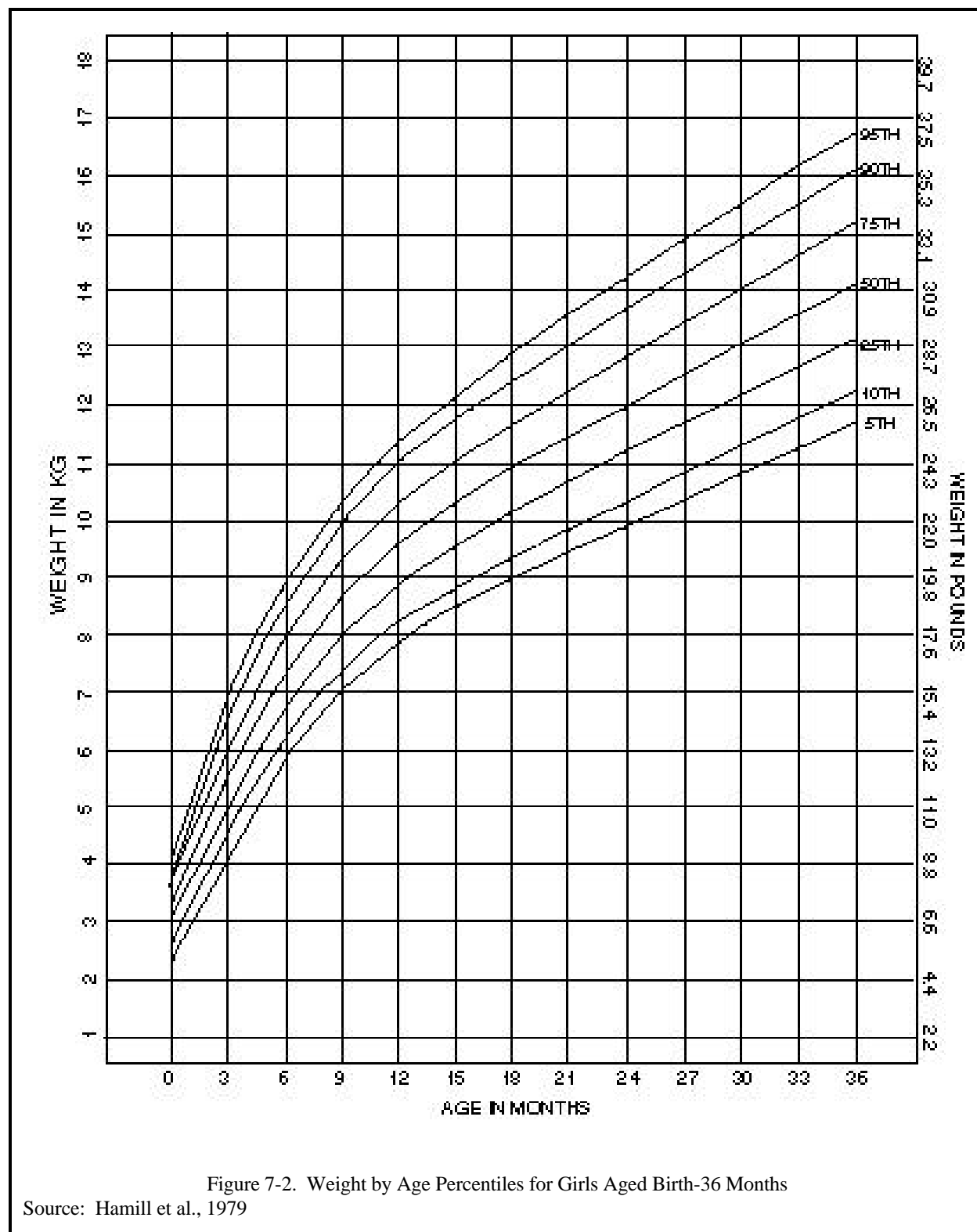


Figure 7-1. Weight by Age Percentiles for Boys Aged Birth-36 Months

Source: Hamill et al., 1979.





that 15 years old. However, this study does provide body weight data for infants less than 6 months old.

NCHS (1987) - *Anthropometric Reference Data and Prevalence of Overweight, United States, 1976-80* - Statistics on anthropometric measurements, including body weight, for the U.S. population were collected by NCHS through the second National Health and Nutrition Examination Survey (NHANES II). NHANES II was conducted on a nationwide probability sample of approximately 28,000 persons, aged 6 months to 74 years, from the civilian, non-institutionalized population of the United States. Of the 28,000 persons, 20,322 were interviewed and examined, resulting in a response rate of 73.1 percent. The survey began in February 1976 and was completed in February 1980. The sample was selected so that certain subgroups thought to be at high risk of malnutrition (persons with low incomes, preschool children, and the elderly) were oversampled. The estimates were weighted to reflect national population estimates. The weighting was accomplished by inflating examination results for each subject by the reciprocal of selection probabilities adjusted to account for those who were not examined, and post stratifying by race, age, and sex (NCHS, 1987).

The NHANES II collected standard body measurements of sample subjects, including height and weight, that were made at various times of the day and in different seasons of the year. This technique was used because one's weight may vary between winter and summer and may fluctuate with recency of food and water intake and other daily activities (NCHS, 1987). Mean body weights of adults, by age, and their standard deviations are presented in Table 7-2 for men, women, and both sexes combined. Mean body weights and standard deviations for children, ages 6 months to 19 years, are presented in Table 7-3 for boys, girls, and boys and girls combined. Percentile distributions of the body weights of adults by age and race for males are presented in Table 7-4, and for females in Table 7-5. Data for children by age are presented in Table 7-6 for males, and for females in Table 7-7.

Results shown in Tables 7-4 and 7-5 indicate that the mean weight for adult males is 78.1 kg and for adult females, 65.4 kg. It also shows that the mean weight for White males (78.5 kg) is greater than for Black males (77.9 kg). Additionally, mean weights are greater for Black females (71.2 kg) than for White females (64.8 kg). From Table 7-3, the mean body weights for girls and boys are approximately the same from ages 6 months to 14 years. Starting at years 15-19, the difference in mean body weight ranges from 6 to 11 kg.

Table 7-2. Body Weights of Adults^a (kilograms)

| Age (years) | Men | | Women | | Men and Women |
|-------------|-----------|-----------|-----------|-----------|---------------|
| | Mean (kg) | Std. Dev. | Mean (kg) | Std. Dev. | Mean (kg) |
| 18 < 25 | 73.8 | 12.7 | 60.6 | 11.9 | 67.2 |
| 25 < 35 | 78.7 | 13.7 | 64.2 | 15.0 | 71.5 |
| 35 < 45 | 80.9 | 13.4 | 67.1 | 15.2 | 74.0 |
| 45 < 55 | 80.9 | 13.6 | 68.0 | 15.3 | 74.5 |
| 55 < 65 | 78.8 | 12.8 | 67.9 | 14.7 | 73.4 |
| 65 < 75 | 74.8 | 12.8 | 66.6 | 13.8 | 70.7 |
| 18 < 75 | 78.1 | 13.5 | 65.4 | 14.6 | 71.8 |

Note: 1 kg = 2.2046 pounds.

^a Includes clothing weight, estimated as ranging from 0.09 to 0.28 kilogram.

Source: Adapted from National Center for Health Statistics (NCHS), 1987.

Table 7-3. Body Weights of Children^a (kilograms)

| Age | Boys | | Girls | | Boys and Girls |
|-------------|-----------|-----------|-----------|-----------|----------------|
| | Mean (kg) | Std. Dev. | Mean (kg) | Std. Dev. | Mean (kg) |
| 6-11 months | 9.4 | 1.3 | 8.8 | 1.2 | 9.1 |
| 1 year | 11.8 | 1.9 | 10.8 | 1.4 | 11.3 |
| 2 years | 13.6 | 1.7 | 13.0 | 1.5 | 13.3 |
| 3 years | 15.7 | 2.0 | 14.9 | 2.1 | 15.3 |
| 4 years | 17.8 | 2.5 | 17.0 | 2.4 | 17.4 |
| 5 years | 19.8 | 3.0 | 19.6 | 3.3 | 19.7 |
| 6 years | 23.0 | 4.0 | 22.1 | 4.0 | 22.6 |
| 7 years | 25.1 | 3.9 | 24.7 | 5.0 | 24.9 |
| 8 years | 28.2 | 6.2 | 27.9 | 5.7 | 28.1 |
| 9 years | 31.1 | 6.3 | 31.9 | 8.4 | 31.5 |
| 10 years | 36.4 | 7.7 | 36.1 | 8.0 | 36.3 |
| 11 years | 40.3 | 10.1 | 41.8 | 10.9 | 41.1 |
| 12 years | 44.2 | 10.1 | 46.4 | 10.1 | 45.3 |
| 13 years | 49.9 | 12.3 | 50.9 | 11.8 | 50.4 |
| 14 years | 57.1 | 11.0 | 54.8 | 11.1 | 56.0 |
| 15 years | 61.0 | 11.0 | 55.1 | 9.8 | 58.1 |
| 16 years | 67.1 | 12.4 | 58.1 | 10.1 | 62.6 |
| 17 years | 66.7 | 11.5 | 59.6 | 11.4 | 63.2 |
| 18 years | 71.1 | 12.7 | 59.0 | 11.1 | 65.1 |
| 19 years | 71.7 | 11.6 | 60.2 | 11.0 | 66.0 |

Note: 1 kg = 2.2046 pounds.

^a Includes clothing weight, estimated as ranging from 0.09 to 0.28 kilogram.

Source: Adapted from National Center for Health Statistics (NCHS), 1987.

7.2. RELEVANT BODY WEIGHT STUDIES

Brainard and Burmaster (1992) - Bivariate Distributions for Height and Weight of Men and Women in the United States - Brainard and Burmaster (1992) examined data on the height and weight of adults published by the U.S. Public Health Service and fit bivariate distributions to the tabulated values for men and women, separately.

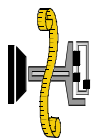


Table 7-4. Weight in Kilograms for Males 18-74 Years of Age--Number Examined, Mean, Standard Deviation, and Selected Percentiles, by Race and Age: United States, 1976-1980^a

| Race and Age | Number of Persons Examined | Mean (kg) | Standard Deviation | Percentile | | | | | | | | |
|------------------------------|----------------------------------|--------------|-----------------------|----------------|------|------|------|------|------|-------|-------|-------|
| | | | | 5th | 10th | 15th | 25th | 50th | 75th | 85th | 90th | 95th |
| <u>All races^b</u> | | | | | | | | | | | | |
| 18-74 years | 5,916 | 78.1 | 13.5 | 58.6 | 62.3 | 64.9 | 68.7 | 76.9 | 85.6 | 91.3 | 95.7 | 102.7 |
| 18-24 years | 988 | 73.8 | 12.7 | 56.8 | 60.4 | 61.9 | 64.8 | 72.0 | 80.3 | 85.1 | 90.4 | 99.5 |
| 25-34 years | 1,067 | 78.7 | 13.7 | 59.5 | 62.9 | 65.4 | 69.3 | 77.5 | 85.6 | 91.1 | 95.1 | 102.7 |
| 35-44 years | 745 | 80.9 | 13.4 | 59.7 | 65.1 | 67.7 | 72.1 | 79.9 | 88.1 | 94.8 | 98.8 | 104.3 |
| 45-54 years | 690 | 80.9 | 13.6 | 50.8 | 65.2 | 67.2 | 71.7 | 79.0 | 89.4 | 94.5 | 99.5 | 105.3 |
| 55-64 years | 1,227 | 78.8 | 12.8 | 59.9 | 63.8 | 66.4 | 70.2 | 77.7 | 85.6 | 90.5 | 94.7 | 102.3 |
| 65-74 years | 1,199 | 74.8 | 12.8 | 54.4 | 58.5 | 61.2 | 66.1 | 74.2 | 82.7 | 87.9 | 91.2 | 96.6 |
| <u>White</u> | | | | | | | | | | | | |
| 18-74 years | 5,148 | 78.5 | 13.1 | 59.3 | 62.8 | 65.5 | 69.4 | 77.3 | 85.6 | 91.4 | 95.5 | 102.3 |
| 18-24 years | 846 | 74.2 | 12.8 | 56.8 | 60.5 | 62.0 | 65.0 | 72.4 | 80.6 | 85.5 | 91.0 | 100.0 |
| 25-34 years | 901 | 79.0 | 13.1 | 59.9 | 63.7 | 65.9 | 69.8 | 78.0 | 85.6 | 91.3 | 95.3 | 102.7 |
| 35-44 years | 653 | 81.4 | 12.8 | 62.3 | 66.6 | 68.8 | 72.9 | 80.1 | 88.2 | 94.6 | 98.7 | 104.1 |
| 45-54 years | 617 | 81.0 | 13.4 | 62.0 | 66.1 | 67.3 | 71.9 | 79.0 | 89.4 | 94.2 | 99.0 | 104.5 |
| 55-64 years | 1,086 | 78.9 | 12.4 | 60.5 | 64.5 | 66.6 | 70.6 | 78.2 | 85.6 | 90.4 | 94.5 | 101.7 |
| 65-74 years | 1,045 | 75.4 | 12.4 | 55.5 | 59.5 | 62.5 | 67.0 | 74.7 | 83.0 | 87.9 | 91.2 | 96.0 |
| <u>Black</u> | | | | | | | | | | | | |
| 18-74 years | 649 | 77.9 | 15.2 | 58.0 | 61.1 | 63.6 | 67.2 | 75.3 | 85.4 | 92.9 | 98.3 | 105.4 |
| 18-24 years | 121 | 72.2 | 12.0 | 58.3 | 60.9 | 62.3 | 64.9 | 70.8 | 77.1 | 81.8 | 83.7 | 93.6 |
| 25-34 years | 139 | 78.2 | 16.3 | 58.7 | 63.4 | 64.9 | 68.4 | 75.3 | 84.4 | 90.6 | 92.2 | 106.3 |
| 35-44 years | 70 | 82.5 | 15.4 | * ^c | 61.7 | 65.2 | 69.7 | 83.1 | 94.8 | 100.4 | 104.2 | * |
| 45-54 years | 62 | 82.4 | 14.5 | * | 64.7 | 67.0 | 73.2 | 81.8 | 93.0 | 100.0 | 102.5 | * |
| 55-64 years | 129 | 78.6 | 14.7 | 56.8 | 61.4 | 64.3 | 68.0 | 77.0 | 86.5 | 93.8 | 98.6 | 104.7 |
| 65-74 years | 128 | 73.3 | 15.3 | 52.5 | 56.7 | 58.0 | 61.0 | 71.2 | 81.1 | 90.8 | 97.3 | 105.1 |

Note: 1 kg = 2.2046 pounds.

^a Includes clothing weight, estimated as ranging from 0.09 to 0.28 kilogram.

^b Includes all other races not shown as separate categories.

^c Data not available.

Source: National Center for Health Statistics, 1987.

Table 7-5. Weight in Kilograms for Females 18-74 Years of Age--Number Examined, Mean, Standard Deviation, and Selected Percentiles, by Race and Age: United States, 1976-1980^a

| Deviation, and Selected Percentiles, by Race and Age: United States, 1976-1980 | | | | | | | | | | | | |
|--|----------------------------------|--------------|-----------------------|------------|------|------|------|------|------|------|-------|-------|
| Race and Age | Number of Persons Examined | Mean (kg) | Standard Deviation | Percentile | | | | | | | | |
| | | | | 5th | 10th | 15th | 25th | 50th | 75th | 85th | 90th | 95th |
| <u>All races^b</u> | | | | | | | | | | | | |
| 18-74 years | 6,588 | 65.4 | 14.6 | 47.7 | 50.3 | 52.2 | 55.4 | 62.4 | 72.1 | 79.2 | 84.4 | 93.1 |
| 18-24 years | 1,066 | 60.6 | 11.9 | 46.6 | 49.1 | 50.6 | 53.2 | 58.0 | 65.0 | 70.4 | 75.3 | 82.9 |
| 25-34 years | 1,170 | 64.2 | 15.0 | 47.4 | 49.6 | 51.4 | 54.3 | 60.9 | 69.6 | 78.4 | 84.1 | 93.5 |
| 35-44 years | 844 | 67.1 | 15.2 | 49.2 | 52.0 | 53.3 | 56.9 | 63.4 | 73.9 | 81.7 | 87.5 | 98.9 |
| 45-54 years | 763 | 68.0 | 15.3 | 48.5 | 51.3 | 53.3 | 57.3 | 65.5 | 75.7 | 82.1 | 87.6 | 96.0 |
| 55-64 years | 1,329 | 67.9 | 14.7 | 48.6 | 51.3 | 54.1 | 57.3 | 65.2 | 75.3 | 82.3 | 87.5 | 95.1 |
| 65-74 years | 1,416 | 66.6 | 13.8 | 47.1 | 50.8 | 53.2 | 57.4 | 64.8 | 73.8 | 79.8 | 84.4 | 91.3 |
| <u>White</u> | | | | | | | | | | | | |
| 18-74 years | 5,686 | 64.8 | 14.1 | 47.7 | 50.3 | 52.2 | 55.2 | 62.1 | 71.1 | 77.9 | 83.3 | 91.5 |
| 18-24 years | 892 | 60.4 | 11.6 | 47.3 | 49.5 | 50.8 | 53.3 | 57.9 | 64.8 | 69.7 | 74.3 | 82.4 |
| 25-34 years | 1,000 | 63.6 | 14.5 | 47.3 | 49.5 | 51.3 | 54.0 | 60.6 | 68.9 | 76.3 | 81.5 | 89.7 |
| 35-44 years | 726 | 66.1 | 14.5 | 49.3 | 51.8 | 52.9 | 56.3 | 62.4 | 71.9 | 79.7 | 85.8 | 94.9 |
| 45-54 years | 647 | 67.3 | 14.4 | 48.6 | 51.3 | 53.4 | 57.0 | 65.0 | 74.8 | 81.1 | 85.6 | 94.5 |
| 55-64 years | 1,176 | 67.2 | 14.4 | 48.5 | 50.7 | 53.7 | 57.1 | 64.7 | 74.5 | 81.8 | 86.2 | 92.8 |
| 65-74 years | 1,245 | 66.2 | 13.7 | 47.2 | 50.7 | 52.9 | 57.2 | 64.3 | 72.9 | 79.2 | 84.3 | 91.2 |
| <u>Black</u> | | | | | | | | | | | | |
| 18-74 years | 782 | 71.2 | 17.3 | 48.8 | 51.6 | 55.1 | 59.1 | 67.8 | 80.6 | 87.4 | 94.9 | 105.1 |
| 18-24 years | 147 | 63.1 | 13.9 | 46.2 | 49.0 | 50.6 | 53.8 | 60.4 | 70.0 | 75.8 | 79.1 | 89.3 |
| 25-34 years | 145 | 69.3 | 16.7 | 48.3 | 50.8 | 53.1 | 57.8 | 65.3 | 80.2 | 87.1 | 91.5 | 102.7 |
| 35-44 years | 103 | 75.3 | 18.4 | 50.7 | 55.2 | 57.2 | 63.0 | 70.2 | 85.2 | 95.3 | 103.5 | 113.1 |
| 45-54 years | 100 | 77.7 | 18.8 | 55.1 | 60.3 | 60.8 | 64.5 | 74.3 | 83.6 | 94.5 | 98.2 | 117.5 |
| 55-64 years | 135 | 75.8 | 16.4 | 54.2 | 55.2 | 57.6 | 65.4 | 74.6 | 83.4 | 91.9 | 95.5 | 108.5 |
| 65-74 years | 152 | 72.4 | 13.6 | 52.9 | 56.4 | 60.3 | 64.0 | 70.0 | 82.2 | 84.4 | 86.5 | 98.1 |

Note: 1 kg = 2.2046 pounds.

^a Includes clothing weight, estimated as ranging from 0.09 to 0.28 kilogram.^b Includes all other races not shown as separate categories.

Source: National Center for Health Statistics, 1987.

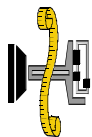


Table 7-6. Weight in Kilograms for Males 6 Months-19 Years of Age--Number Examined, Mean, Standard Deviation, and Selected Percentiles, by Sex and Age: United States, 1976-1980^a

| Age | Number of Persons Examined | Mean (kg) | Standard Deviation | Percentile | | | | | | | | |
|-------------------|----------------------------------|--------------|-----------------------|------------|------|------|------|------|------|------|------|------|
| | | | | 5th | 10th | 15th | 25th | 50th | 75th | 85th | 90th | 95th |
| 6-11 months | 179 | 9.4 | 1.3 | 7.5 | 7.6 | 8.2 | 8.6 | 9.4 | 10.1 | 10.7 | 10.9 | 11.4 |
| 1 years | 370 | 11.8 | 1.9 | 9.6 | 10.0 | 10.3 | 10.8 | 11.7 | 12.6 | 13.1 | 13.6 | 14.4 |
| 2 years | 375 | 13.6 | 1.7 | 11.1 | 11.6 | 11.8 | 12.6 | 13.5 | 14.5 | 15.2 | 15.8 | 16.5 |
| 3 years | 418 | 15.7 | 2.0 | 12.9 | 13.5 | 13.9 | 14.4 | 15.4 | 16.8 | 17.4 | 17.9 | 19.1 |
| 4 years | 404 | 17.8 | 2.5 | 14.1 | 15.0 | 15.3 | 16.0 | 17.6 | 19.0 | 19.9 | 20.9 | 22.2 |
| 5 years | 397 | 19.8 | 3.0 | 16.0 | 16.8 | 17.1 | 17.7 | 19.4 | 21.3 | 22.9 | 23.7 | 25.4 |
| 6 years | 133 | 23.0 | 4.0 | 18.6 | 19.2 | 19.8 | 20.3 | 22.0 | 24.1 | 26.4 | 28.3 | 30.1 |
| 7 years | 148 | 25.1 | 3.9 | 19.7 | 20.8 | 21.2 | 22.2 | 24.8 | 26.9 | 28.2 | 29.6 | 33.9 |
| 8 years | 147 | 28.2 | 6.2 | 20.4 | 22.7 | 23.6 | 24.6 | 27.5 | 29.9 | 33.0 | 35.5 | 39.1 |
| 9 years | 145 | 31.1 | 6.3 | 24.0 | 25.6 | 26.0 | 27.1 | 30.2 | 33.0 | 35.4 | 38.6 | 43.1 |
| 10 years | 157 | 36.4 | 7.7 | 27.2 | 28.2 | 29.6 | 31.4 | 34.8 | 39.2 | 43.5 | 46.3 | 53.4 |
| 11 years | 155 | 40.3 | 10.1 | 26.8 | 28.8 | 31.8 | 33.5 | 37.3 | 46.4 | 52.0 | 57.0 | 61.0 |
| 12 years | 145 | 44.2 | 10.1 | 30.7 | 32.5 | 35.4 | 37.8 | 42.5 | 48.8 | 52.6 | 58.9 | 67.5 |
| 13 years | 173 | 49.9 | 12.3 | 35.4 | 37.0 | 38.3 | 40.1 | 48.4 | 56.3 | 59.8 | 64.2 | 69.9 |
| 14 years | 186 | 57.1 | 11.0 | 41.0 | 44.5 | 46.4 | 49.8 | 56.4 | 63.3 | 66.1 | 68.9 | 77.0 |
| 15 years | 184 | 61.0 | 11.0 | 46.2 | 49.1 | 50.6 | 54.2 | 60.1 | 64.9 | 68.7 | 72.8 | 81.3 |
| 16 years | 178 | 67.1 | 12.4 | 51.4 | 54.3 | 56.1 | 57.6 | 64.4 | 73.6 | 78.1 | 82.2 | 91.2 |
| 17 years | 173 | 66.7 | 11.5 | 50.7 | 53.4 | 54.8 | 58.8 | 65.8 | 72.0 | 76.8 | 82.3 | 88.9 |
| 18 years | 164 | 71.1 | 12.7 | 54.1 | 56.6 | 60.3 | 61.9 | 70.4 | 76.6 | 80.0 | 83.5 | 95.3 |
| 19 years | 148 | 71.7 | 11.6 | 55.9 | 57.9 | 60.5 | 63.8 | 69.5 | 77.9 | 84.3 | 86.8 | 92.1 |

Note: 1 kg = 2.2046 pounds.

^a Includes clothing weight, estimated as ranging from 0.09 to 0.28 kilogram.

Source: National Center for Health Statistics, 1987.

Table 7-7. Weight in Kilograms for Females 6 Months-19 Years of Age--Number Examined, Mean, Standard Deviation, and Selected Percentiles, by Sex and Age: United States, 1976-1980^a

| Age | Number of Persons Examined | Mean (kg) | Standard Deviation | Percentile | | | | | | | | |
|-------------------|----------------------------------|--------------|-----------------------|------------|------|------|------|------|------|------|------|------|
| | | | | 5th | 10th | 15th | 25th | 50th | 75th | 85th | 90th | 95th |
| 6-11 months | 177 | 8.8 | 1.2 | 6.6 | 7.3 | 7.5 | 7.9 | 8.9 | 9.4 | 10.1 | 10.4 | 10.9 |
| 1 years | 336 | 10.8 | 1.4 | 8.8 | 9.1 | 9.4 | 9.9 | 10.7 | 11.7 | 12.4 | 12.7 | 13.4 |
| 2 years | 336 | 13.0 | 1.5 | 10.8 | 11.2 | 11.6 | 12.0 | 12.7 | 13.8 | 14.5 | 14.9 | 15.9 |
| 3 years | 366 | 14.9 | 2.1 | 11.7 | 12.3 | 12.9 | 13.4 | 14.7 | 16.1 | 17.0 | 17.4 | 18.4 |
| 4 years | 396 | 17.0 | 2.4 | 13.7 | 14.3 | 14.5 | 15.2 | 16.7 | 18.4 | 19.3 | 20.2 | 21.1 |
| 5 years | 364 | 19.6 | 3.3 | 15.3 | 16.1 | 16.7 | 17.2 | 19.0 | 21.2 | 22.8 | 24.7 | 26.6 |
| 6 years | 135 | 22.1 | 4.0 | 17.0 | 17.8 | 18.6 | 19.3 | 21.3 | 23.8 | 26.6 | 28.9 | 29.6 |
| 7 years | 157 | 24.7 | 5.0 | 19.2 | 19.5 | 19.8 | 21.4 | 23.8 | 27.1 | 28.7 | 30.3 | 34.0 |
| 8 years | 123 | 27.9 | 5.7 | 21.4 | 22.3 | 23.3 | 24.4 | 27.5 | 30.2 | 31.3 | 33.2 | 36.5 |
| 9 years | 149 | 31.9 | 8.4 | 22.9 | 25.0 | 25.8 | 27.0 | 29.7 | 33.6 | 39.3 | 43.3 | 48.4 |
| 10 years | 136 | 36.1 | 8.0 | 25.7 | 27.5 | 29.0 | 31.0 | 34.5 | 39.5 | 44.2 | 45.8 | 49.6 |
| 11 years | 140 | 41.8 | 10.9 | 29.8 | 30.3 | 31.3 | 33.9 | 40.3 | 45.8 | 51.0 | 56.6 | 60.0 |
| 12 years | 147 | 46.4 | 10.1 | 32.3 | 35.0 | 36.7 | 39.1 | 45.4 | 52.6 | 58.0 | 60.5 | 64.3 |
| 13 years | 162 | 50.9 | 11.8 | 35.4 | 39.0 | 40.3 | 44.1 | 49.0 | 55.2 | 60.9 | 66.4 | 76.3 |
| 14 years | 178 | 54.8 | 11.1 | 40.3 | 42.8 | 43.7 | 47.4 | 53.1 | 60.3 | 65.7 | 67.6 | 75.2 |
| 15 years | 145 | 55.1 | 9.8 | 44.0 | 45.1 | 46.5 | 48.2 | 53.3 | 59.6 | 62.2 | 65.5 | 76.6 |
| 16 years | 170 | 58.1 | 10.1 | 44.1 | 47.3 | 48.9 | 51.3 | 55.6 | 62.5 | 68.9 | 73.3 | 76.8 |
| 17 years | 134 | 59.6 | 11.4 | 44.5 | 48.9 | 50.5 | 52.2 | 58.4 | 63.4 | 68.4 | 71.6 | 81.8 |
| 18 years | 170 | 59.0 | 11.1 | 45.3 | 49.5 | 50.8 | 52.8 | 56.4 | 63.0 | 66.0 | 70.1 | 78.0 |
| 19 years | 158 | 60.2 | 11.0 | 48.5 | 49.7 | 51.7 | 53.9 | 57.1 | 64.4 | 70.7 | 74.8 | 78.1 |

Note: 1 kg = 2.2046 pounds.

^a Includes clothing weight, estimated as ranging from 0.09 to 0.28 kilogram.

Source: National Center for Health Statistics, 1987.



Chapter 7 - Body Weight Studies

Height and weight of 5,916 men and 6,588 women in the age range of 18 to 74 years were taken from the NHANES II study and statistically adjusted to represent the U.S. population aged 18 to 74 years with regard to age structure, sex, and race. Estimation techniques were used to fit normal distributions to the cumulative marginal data and goodness-of-fit tests were used to test the hypothesis that height and lognormal weight follow a normal distribution for each sex. It was found that the marginal distributions of height and lognormal weight for both men and women are Gaussian (normal) in form. This conclusion was reached by visual observation and the high R^2 values for best-fit lines obtained using linear regression. The R^2 values for men's height and lognormal weight are reported to be 0.999. The R^2 values for women's height and lognormal weight are 0.999 and 0.985, respectively.

Brainard and Burmaster (1992) fit bivariate distributions to estimated numbers of men and women aged 18 to 74 years in cells representing 1 inch height intervals and 10 pound weight intervals. Adjusted height and lognormal weight data for men were fit to a single bivariate normal distribution with an estimated mean height of 1.75 meters (69.2 inches) and an estimated mean weight of 78.6 kg (173.2 pounds). For women, height and lognormal weight data were fit to a pair of superimposed bivariate normal distributions (Brainard and Burmaster, 1992). The average height and weight for women were estimated from the combined bivariate analyses. Mean height for women was estimated to be 1.62 meters (63.8 inches) and mean weight was estimated to be 65.8 kg (145.0 pounds). For women, a calculation using a single bivariate normal distribution gave poor results (Brainard and Burmaster, 1992). According to Brainard and Burmaster, the distributions are suitable for use in Monte Carlo simulation.

Burmaster et al. (1994) (*Submitted 2/19/94 to Risk Analysis for Publication*) - *Lognormal Distributions of Body Weight as a Function of Age for Female and Male Children in the United States* - Burmaster et al. (1994), performed data analysis to fit normal and lognormal distributions to the body weights of female and male children at age 6 months to 20 years (Burmaster et al., 1994).

Data used in this analysis were from the second survey of the National Center for Health Statistics, NHANES II, which included responses from 4,079

females and 4,379 males 6 months to 20 years of age in the U.S. (Burmaster et al., 1994). The NHANES II data had been statistically adjusted for non-response and probability of selection, and stratified by age, sex, and race to reflect the entire U.S. population prior to reporting (Burmaster et al., 1994). Burmaster et al. (1994) conducted exploratory and quantitative data analyses, and fit normal and lognormal distributions to percentiles of body weight for children. Cumulative distribution functions (CDFs) were plotted for female and male body weights on both linear and logarithmic scales.

Two models were used to assess the probability density functions (PDFs) of children's body weight. Linear and quadratic regression lines were fitted to the data. A number of goodness-of-fit measures were conducted on data generated by the two models. Burmaster et al. (1994) found that lognormal distributions give strong fits to the body weights of children, ages 6 months to 20 years. Statistics for the lognormal probability plots are presented in Tables 7-8 and 7-9. These data can be used for further analyses of body weight distribution (i.e., application of Monte Carlo analysis).

Table 7-8. Statistics for Probability Plot Regression Analyses
Female's Body Weights 6 Months to 20 Years of Age

| Age | Lognormal Probability Plots | |
|--------------------|-----------------------------|--------------|
| | Linear Curve | |
| | μ_2^a | σ_2^a |
| 6 months to 1 year | 2.16 | 0.145 |
| 1 to 2 years | 2.38 | 0.128 |
| 2 to 3 years | 2.56 | 0.112 |
| 3 to 4 years | 2.69 | 0.137 |
| 4 to 5 years | 2.83 | 0.133 |
| 5 to 6 years | 2.98 | 0.163 |
| 6 to 7 years | 3.10 | 0.174 |
| 7 to 8 years | 3.19 | 0.174 |
| 8 to 9 years | 3.31 | 0.156 |
| 9 to 10 years | 3.46 | 0.214 |
| 10 to 11 years | 3.57 | 0.199 |
| 11 to 12 years | 3.71 | 0.226 |
| 12 to 13 years | 3.82 | 0.213 |
| 13 to 14 years | 3.92 | 0.216 |
| 14 to 15 years | 3.99 | 0.187 |
| 15 to 16 years | 4.00 | 0.156 |
| 16 to 17 years | 4.06 | 0.167 |
| 17 to 18 years | 4.08 | 0.165 |
| 18 to 19 years | 4.07 | 0.147 |
| 19 to 20 years | 4.10 | 0.149 |

^a μ_2 , σ_2 - correspond to the mean and standard deviation, respectively, of the lognormal distribution of body weight (kg).

Source: Burmaster et al., 1994.

Table 7-9. Statistics for Probability Plot Regression Analyses



| Age | Lognormal Probability Plots Linear Curve | |
|--------------------|---|--------------|
| | μ_2^a | σ_2^a |
| 6 months to 1 year | 2.23 | 0.132 |
| 1 to 2 years | 2.46 | 0.119 |
| 2 to 3 years | 2.60 | 0.120 |
| 3 to 4 years | 2.75 | 0.114 |
| 4 to 5 years | 2.87 | 0.133 |
| 5 to 6 years | 2.99 | 0.138 |
| 6 to 7 years | 3.13 | 0.145 |
| 7 to 8 years | 3.21 | 0.151 |
| 8 to 9 years | 3.33 | 0.181 |
| 9 to 10 years | 3.43 | 0.165 |
| 10 to 11 years | 3.59 | 0.195 |
| 11 to 12 years | 3.69 | 0.252 |
| 12 to 13 years | 3.78 | 0.224 |
| 13 to 14 years | 3.88 | 0.215 |
| 14 to 15 years | 4.02 | 0.181 |
| 15 to 16 years | 4.09 | 0.159 |
| 16 to 17 years | 4.20 | 0.168 |
| 17 to 18 years | 4.19 | 0.167 |
| 18 to 19 years | 4.25 | 0.159 |
| 19 to 20 years | 4.26 | 0.154 |

^a μ_2 , σ_2 - correspond to the mean and standard deviation, respectively, of the lognormal distribution of body weight (kg).
Source: Burmaster et al., 1994.

AIHC - Exposure Factors Sourcebook - The Exposure Factors Sourcebook (AIHC, 1994) provides similar body weight data as presented here. Consistent with this document, an average adult body weight of 72 kg is recommended on the basis of the NHANES II data (NCHS, 1987). These data are also used to derive probability distributions for adults and children. In addition, the Sourcebook presents probability distributions derived by Brainard and Burmaster (1992), Versar (1991) and Brorby and Finley (1993). For each distribution, the @Risk formula is provided for direct use in the @Risk simulation software (Palisade, 1992). The organization of this document, makes it very convenient to use in support of Monte Carlo analysis. The reviews of the supporting studies are very brief with little analysis of their strengths and weaknesses. The Sourcebook has been classified as a relevant rather than key study because it is not the primary source for the data used to make recommendations in this document. The Sourcebook is very similar to this document in the sense that it summarizes exposure factor data and recommends values. As such, it is clearly relevant as an alternative information source on body weights as well as other exposure factors.

7.3. RECOMMENDATIONS

The key studies described in this section was used in selecting recommended values for body weight. The general description of both the key and relevant studies are summarized in Table 7-10. The recommendations for body weight are summarized in Table 7-11. Table 7-12 presents the confidence ratings for body weight recommendations. The mean body weight for all adults (male and female, all age groups) combined is 71.8 kg as shown in Table 7-2. The mean values for each age group in Table 7-2 were derived by adding the body weights for men and women and dividing by 2. If age and sex distribution of the exposed population is known, the mean body weight values in Table 7-2 can be used. If percentile data are needed or if race is a factor, Tables 7-4 and 7-5 can be used to select the appropriate data for percentiles or mean values.

For infants (birth to 6 months), appropriate values for body weight may be selected from Table 7-1. These data (percentile only) are presented for male and female infants.

For children, appropriate mean values for weights may be selected from Table 7-3. If percentile values are needed, these data are presented in Table 7-6 for male children and in Table 7-7 for female children.

Body weight is a function of age, gender, and race and populations of many geographic regions may vary from the general population across geographic regions. Therefore, the user should make appropriate adjustments when applying the percentiles to other geographic regions.

The mean recommended value for adults (71.8 kg) is different than the 70 kg commonly assumed in EPA risk assessments. Assessors are encouraged to use values which most accurately reflect the exposed population. When using values other than 70 kg, however, the assessors should consider if the dose estimate will be used to estimate risk by combining with a dose-response relationship which was derived assuming a body weight of 70 kg. If such an inconsistency exists, the assessor should adjust the dose-response relationship as described in the appendix to Chapter 1. The Integrated Risk Information System (IRIS) does not use a 70 kg body weight assumption in the derivation of RfCs and RfDs, but does make this assumption in the derivation of cancer slope factors and unit risks.

Table 7-10. Summary of Body Weight Studies



Chapter 7 - Body Weight Studies

| Study | Number of Subjects | Population | Comments |
|------------------------------|---------------------------------------|-------------------------|---|
| KEY STUDIES | | | |
| Hamill et al. (1979) | ~1,000 | U.S. general population | Authors noted that data are accurate measurements from a large nationally representative sample of children. |
| NCHS, 1987 (NHANES II) | 20,322 | U.S. general population | Based on civilian non-institutionalized population aged 6 months to 74 years. Response rate was 73.1 percent. |
| RELEVANT STUDIES | | | |
| Brainard and Burmaster, 1992 | 12,501 (5,916 men and 6,588 women) | U.S. general population | Used data from NHANES II to fit bivariate distributions to women and men age 18 to 74 years. |
| Burmaster et al., 1994 | 8,458 (4,079 females and 4,379 males) | U.S. general population | Used data from NHANES II to develop fitted distributions for children aged 6 to 20 years old. Adjusted for non-response by age, gender, and race. |

| Table 7-11. Summary of Recommended Values for Body Weight | | | |
|---|-------------------------|------------------------|------------------------|
| Population | Mean | Upper Percentile | Multiple Percentiles |
| Adults | 71.8 kg (See Table 7-2) | See Tables 7-4 and 7-5 | See Tables 7-4 and 7-5 |
| Children | See Table 7-3 | See Tables 7-6 and 7-7 | See Tables 7-6 and 7-7 |
| Infants | Not Available | See Table 7-1 | See Table 7-1 |

7.4. REFERENCES FOR CHAPTER 7

- American Industrial Health Council (AIHC). (1994) Exposure factors sourcebook. AIHC, Washington, DC.
- Brainard, J.; Burmaster, D. (1992) Bivariate distributions for height and weight of men and women in the United States. *Risk Anal.* 12(2):267-275.
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- National Center for Health Statistics (NCHS) (1987) Anthropometric reference data and prevalence of overweight, United States, 1976-80. Data from the National Health and Nutrition Examination Survey, Series 11, No. 238. Hyattsville, MD: U.S. Department of Health and Human Services, Public Health Service, National Center for Health Statistics. DHHS Publication No. (PHS) 87-1688.
- Palisade. (1992) @Risk Users Guide. Palisade Corporation, Newfield, NY.
- U.S. EPA (1989) Risk assessment guidance for Superfund, Volume I: Human health evaluation manual. Washington, DC: U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. EPA/540/1-89/002.
- Versar, Inc. (1991) Analysis of the impact of exposure assumptions on risk assessment of chemicals in the environment, phase II: uncertainty analyses of existing exposure assessment methods. Draft Report. Prepared for Exposure Assessment Task Group, Chemical Manufacturers Association, Washington, DC.



Table 7-12. Confidence in Body Weight Recommendations

| Considerations | Rationale | Rating |
|---|--|-------------|
| Study Elements | | |
| • Level of peer review | NHANES II was the major source of data for NCHS (1987). This is a published study which received a high level of peer review. The Hamill et al. (1979) is a peer reviewed journal publication. | High |
| • Accessibility | Both studies are available to the public. | High |
| • Reproducibility | Results can be reproduced by analyzing NHANES II data and the Fels Research Institute data. | High |
| • Focus on factor of interest | The studies focused on body weight, the exposure factor of interest. | High |
| • Data pertinent to US | The data represent the U.S. population. | High |
| • Primary data | The primary data were generated from NHANES II data and Fels studies, thus these data are secondary. | Medium |
| • Currency | The data were collected between 1976-1980. | Low |
| • Adequacy of data collection period | The NHANES II study included data collected over a period of 4 years. Body weight measurements were taken at various times of the day and at different seasons of the year. | High |
| • Validity of approach | Direct body weights were measured for both studies. For NHANES II, subgroups at risk for malnutrition were over-sampled. Weighting was accomplished by inflating examination results for those not examined and were stratified by race, age, and sex. The Fels data are from an ongoing longitudinal study where the data are collected regularly. | High |
| • Study size | The sample size consisted of 28,000 persons for NHANES II. Author noted in Hamill et al. (1979) that the data set was large. | High |
| • Representativeness of the population | Data collected focused on the U.S. population for both studies. | High |
| • Characterization of variability | Both studies characterized variability regarding age and sex. Additionally NHANES II characterized race (for Blacks, Whites and total populations) and sampled persons with low income. | High |
| • Lack of bias in study design (high rating is desirable) | There are no apparent biases in the study designs for NHANES II. The study design for collecting the Fels data was not provided. | Medium-High |
| • Measurement error | For NHANES II, measurement error should be low since body weights were performed in a mobile examination center using standardized procedures and equipment. Also, measurements were taken at various times of the day to account for weight fluctuations as a result of recent food or water intake. The authors of Hamill et al. (1979) report that study data are based on accurate direct measurements from an ongoing longitudinal study. | High |
| Other Elements | | |
| • Number of studies | There are two studies. | Low |
| • Agreement between researchers | There is consistency among the two studies. | High |
| Overall Rating | | High |